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TECHNICAL NOTE

ENERGY CONSERVATION IN GREENHOUSES IV. NEW INFRARED-REFLECTIVE COVER MATERIALS

INTRODUCTION

Photosynthesis and other growth processes require light only from the visible portion of the spectrum. Therefore, greenhouse cover materials are rated according to their transparency to visible light. Until recently, the importance of cover response to other portions of the spectrum has been of little interest to manufacturers, who try to optimize the combination of lifespan, R-value, cost, etc. However, one of the most popular materials used in covers, polyethylene, is transparent to the infrared (heat) portion of the spectrum.

RADIANT HEAT LOSS

Any object above the temperature of absolute zero (-273 C) emits and, therefore, loses radiant energy. The temperature of the object determines the wavelength of the energy given off (Fig. 1a). All objects glow in some portion of the spectrum, even if the emitted energy is outside the range of wavelengths visible to the human eye. Specifically, what is generally termed "heat" is actually infrared energy, which can be "seen" by various devices, such as pyrometers or "thermovision" cameras, etc.

Heat energy is radiated in a fashion similar to the way it is conducted. Radiant energy will travel from a warm object to a cooler area (Fig. 1b). On a clear night, a plant inside a heated greenhouse covered with polyethylene radiates infrared energy based on the difference between its surface temperature and the apparent radiant temperature of the clear sky. Cloud cover at night will offset the loss of radiant energy because its radiant temperature is warmer than the clear sky temperature and, under heavily overcast conditions, the apparent temperature of the sky can approach the air temperature at ground level.

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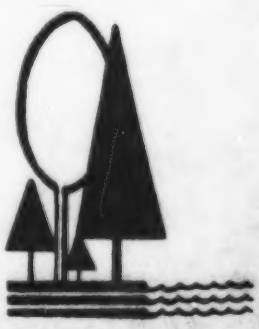

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Because polyethylene is transparent to infrared radiation and does not reflect it back to the crop surface, poly-covered greenhouses have high radiant losses. A new generation of polyethylene additives has been developed to overcome this deficiency and thus save heating dollars.

THE IDEAL COVER

During the daylight hours, an ideal greenhouse cover should be selectively transparent to incoming radiation. Since sunlight is composed primarily of visible and near-infrared components, the cover should be highly transparent to these wavelengths for winter growing. (In summer, all of the near-IR and some of the visible part of the spectrum should be reflected to prevent overheating.)

At night, however, the goal is to minimize radiant loss from the surfaces within the greenhouse. As shown in Figure 1b, the peak wavelength of these losses occurs in a different part of the spectrum - in the far-infrared region. Therefore, the cover should be opaque to far-IR either by absorbing or reflecting these wavelengths. From the viewpoint of radiant energy loss, both glass and polyvinyl chloride (PVC) are close to the ideal cover (Fig. 1c). However, other limitations, like the weight and fragility of glass and size limits on the maximum width of PVC film possible to manufacture, restrict the use of these covers.

THE NEW POLYETHYLENES

In addition to all the other improvements made in the past few years, the new polyethylenes have additives incorporated into the plastic film which absorb large amounts of far-IR radiation (Fig. 1d). Two of these additives are EVA (ethylene vinyl acetate) and inorganic phosphate. By absorbing far-IR energy, the greenhouse cover becomes opaque to far-IR and the temperature gradient is established between the ground or crop and the cover, rather than the deep sky.

Furthermore, although standard polyethylene and IR-absorptive polyethylene transmit the same amount of light, the new IR-absorptive compounds diffuse more of the light entering the greenhouse. As a result, shading lines are diminished and there is better light penetration to the lower needles or leaves of a crop of seedlings. The net result (with vegetable crops) is earlier and heavier yields. With seedlings, better quality and faster growth can be anticipated (Raviv and Allingham 1983).

Energy savings recorded under operational conditions vary. Seasonal decreases in fuel consumption of 15 - 25% have been recorded, with some manufacturers claiming up to 30% reduction compared to similar double polyethylene greenhouses. However, actual savings will depend on the seasonal frequency and intensity of cloud cover. The effect of the IR-absorbing additives is maximized in climates characterized by cold clear night skies. Savings will also depend on the type and amount of additive present in films manufactured by different companies.

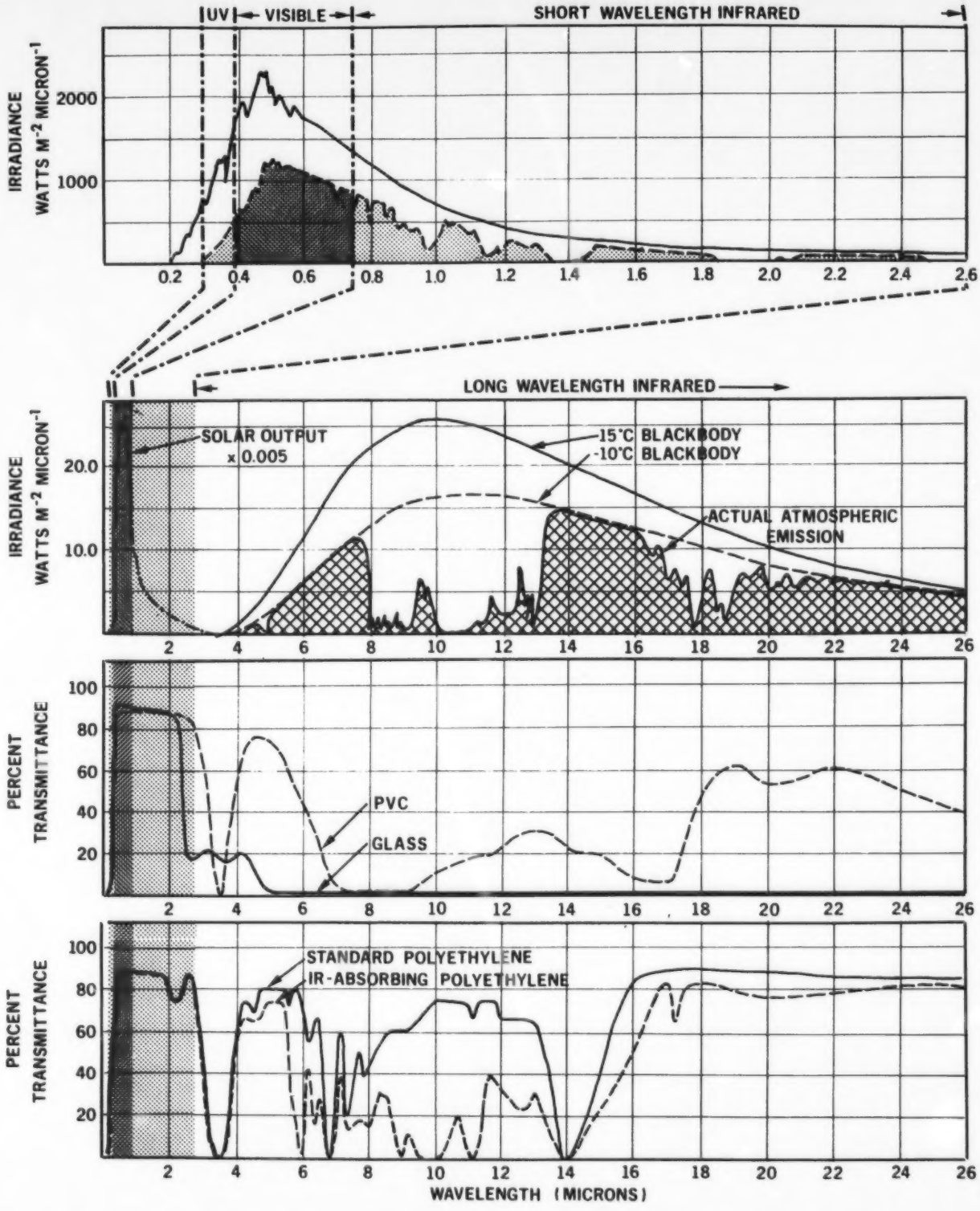

Figure 1. Radiation of heat energy from greenhouses and transmittance of incoming radiation through greenhouse covers; (a) temperature of the object determines the wave length of the energy given off, (b) radiant energy moves from a warm object to a cooler object, (c) polyvinyl chloride and glass are close to ideal covers, and (d) new polyethelenes have additives which absorb large amounts of far-IR radiation.

THE EFFECT OF CONDENSATION

When high humidity is maintained, beads of water form on polyethylene as the temperature of the cover drops below the dewpoint. Some manufacturers add compounds, in addition to the far-IR reflective components, which inhibit condensation. This type of cover usually costs more and there are reports that the condensation-preventing compounds may leach out of the plastic within 5-6 months - long before replacement is normally needed. Therefore, it is necessary to decide whether films with the condensation inhibitors are worth the extra cost.

Condensation reduces the transmission of daylight. Various studies have shown that the presence of water droplets decreases the light intensity at the crop surface by at least 5 - 10% (Raviv and Allingham 1983) and reductions of over 30% have been suggested (Morris 1972). This reduction becomes increasingly detrimental with early (Jan-Feb) germination dates. Anti-condensate films reduce the effects of water droplets by promoting large drop sizes which then either drip or run down the poly surface.

Anti-condensate additives currently appear to be ideal for growers who replace their greenhouse covers every 1-2 years and who germinate crops early in the year during periods of reduced daylight intensity and daylength. Summer cropping regimes and long-life poly covers are probably not worth the extra investment at this time.

FUTURE DEVELOPMENTS

Film manufacturers continue to work toward developing and improving various IR-retentive covers. A new type of plastic film which reflects, rather than absorbs, infrared energy is currently being tested for greenhouse use. This film, used in energy efficient windows (trademarked under the name "Heat Mirror"), will save even more energy than polyethylene- based covers.

Greenhouse companies are also aggressively competing for the market in better condensation inhibitors. Improved covers with long-lasting additives should be widely available within a couple of years.

REFERENCES

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